Influence of TiN microstructure on its dry etch behavior

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TiN is being used for many applications in the micro-electronics industry, both in back-end and front and of line. The deposition of TiN is usually optimized to meet the specifications of different applications and this can have significant influences on the dry etch behavior. However, so far, TiN deposition was not optimized from the dry etch point of view. In this work we study the impact of the TiN microstructure on its dry etching properties and we show that by decreasing the crystallinity of TiN the material becomes easier to etch.

In a previous work we showed that etching of TiN in Cl_2-based chemistries is influenced by its typical columnar structure and crystallographic orientation.[1] TiN crystallites are normal to the surface as shown in Figures 1 and 3 and their surface planes are identically oriented with the orientation depending on the deposition conditions.[2,4] In our former paper we also demonstrated that the {200} planes are etched faster and that by applying a bias voltage of about -180V the surface could be etched uniformly. Therefore it was advised to use {200} oriented TiN films in order to overcome problems related to dry etching. In a recent project, however, we encountered the difficulty where the orientation could not be chosen deliberately since the film was deposited on a high topography structure with a sloped side wall. In that case the surface orientation of TiN is determined by the angle of the slope of the substrate. Since the slope is about 45°, the TiN crystallites presumably have {110} orientations.[3] (Figure 1) This was also shown in a similar experiment by Rausenbach et al.[4] As a consequence we found indeed that it was much harder to etch the TiN from the sloped surface which resulted in residues after etching (Figure 2). Therefore, we tried to make the TiN film less crystalline so that the surface orientation of the film would have smaller impact on the dry etch process.

In particular, we aimed to reduce the crystallinity by increasing the energy of the impacting ions during the deposition process which was previously demonstrated by Tanaka et al.[5] XRD spectra in Figure 4 show that this is a valid approach and that for the sample deposited with 580W bias power the crystallinity is reduced the most since the peak intensities are the lowest. Another advantage of the deposition at high bias is that the film on the slope is thinner probably because at the 45° angle more material is resputtered from the surface during deposition.[6] Note that also for the standard deposition process the film is thinner on the slope, since the flux of ions per surface area is smaller (Figures 3a and b). Tests on blanket films proved that the etch rate of samples deposited with increased bias is higher and are thus easier to etch. The etch rate of the film on the slope was still lower, probably because the flux of etching species per area is smaller but since the film was thinner it could be removed in the same time as the rest of the film on the flat surface (Figure5). Other properties of the TiN film, like electrical resistance, stress, and density were measured but the higher bias power during deposition was found to have only a marginal effect.

Thus, it is concluded that by decreasing the crystallinity of TiN, the films become easier to etch, while other film properties are preserved. Therefore this is a simple strategy which can be used where difficulties with etching TiN are encountered.

Figures:

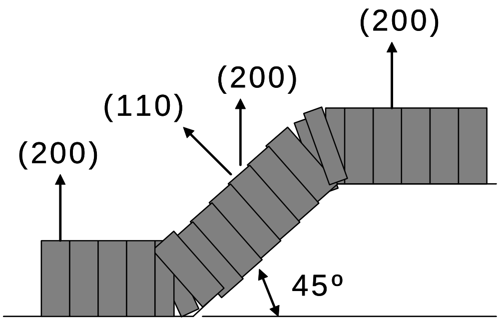

Figure 1: Structure of TiN on a sloped surface

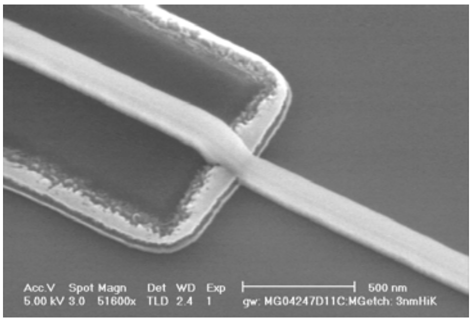

Figure 2: Tilted SEM picture of TiN residues on a sloped surface after etching

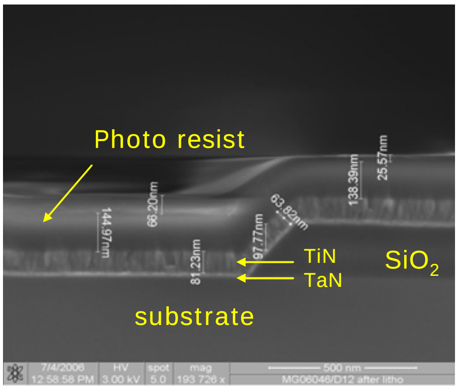

Figure 3a: Cross-section SEM picture showing a standard TiN deposited on a sloped surface (bias power during deposition: 200W)

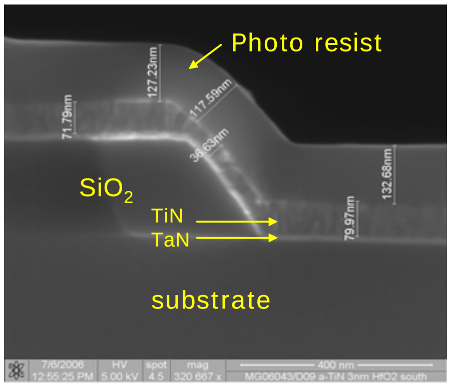

Figure 3b: Cross-section SEM picture showing the conformality of TiN deposited on a sloped surface with high bias power (bias power during deposition: 580W)

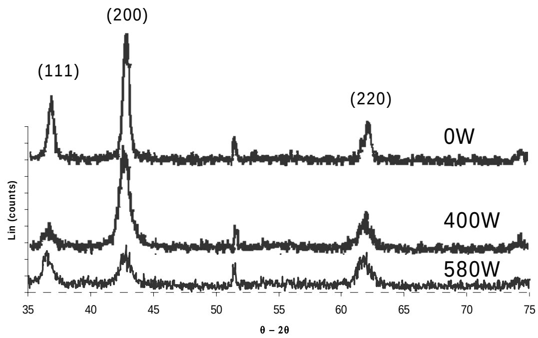

Figure 4: XRD spectra of TiN deposited with different bias power during deposition (different graphs are on the same scale but shifted for clarity)

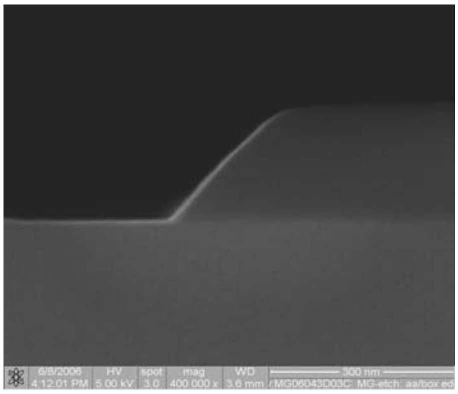

Figure 5: Cross-section SEM piture showing a surface which is successfully cleared of TiN

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